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14. ABSTRACT

Bypassing evolution
Hemispheric attention
Fitting the task to the brain
Fitting the brain to the task
Remaining issues

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Report Title

Optimizing Human Attention

ABSTRACT

Bypassing evolution
Hemispheric attention
Fitting the task to the brain
Fitting the brain to the task
Remaining issues

Optimizing Human Cognition

Eran Zaidel
Department of Psychology
and Brain Research Institute
UCLA

- Bypassing evolution
- Hemispheric attention
- Fitting the task to the brain
- Fitting the brain to the task
- Remaining issues

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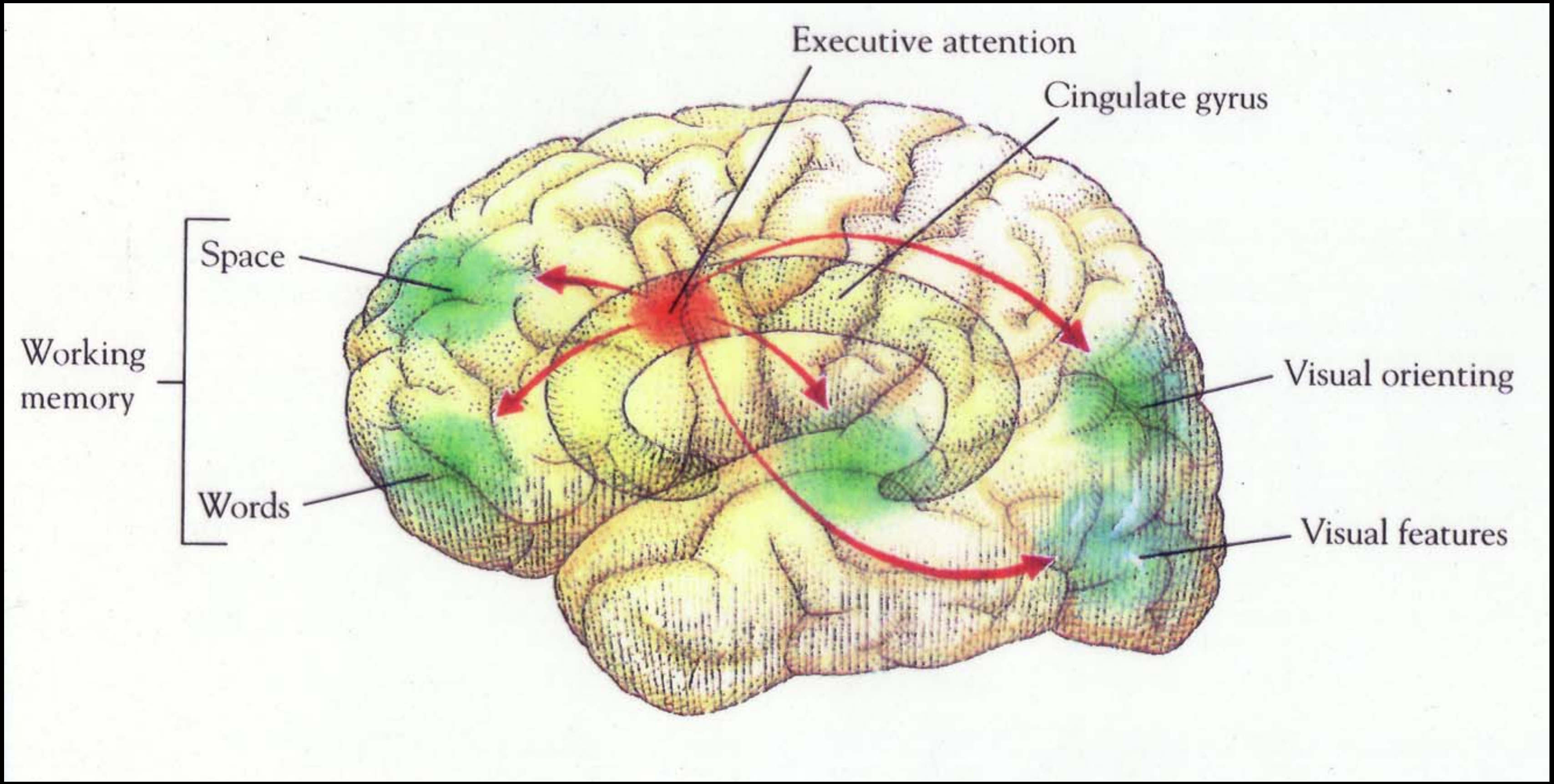
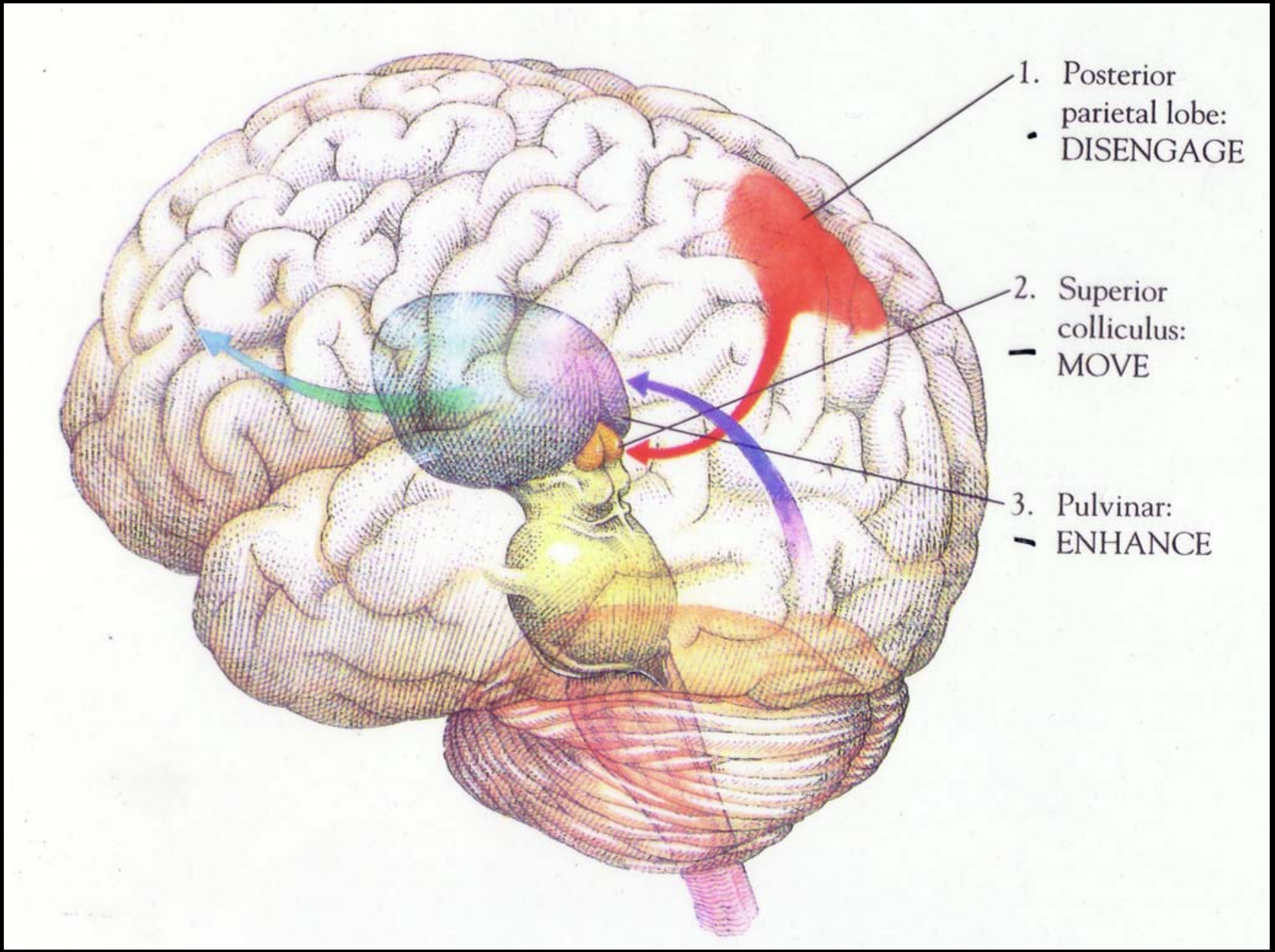
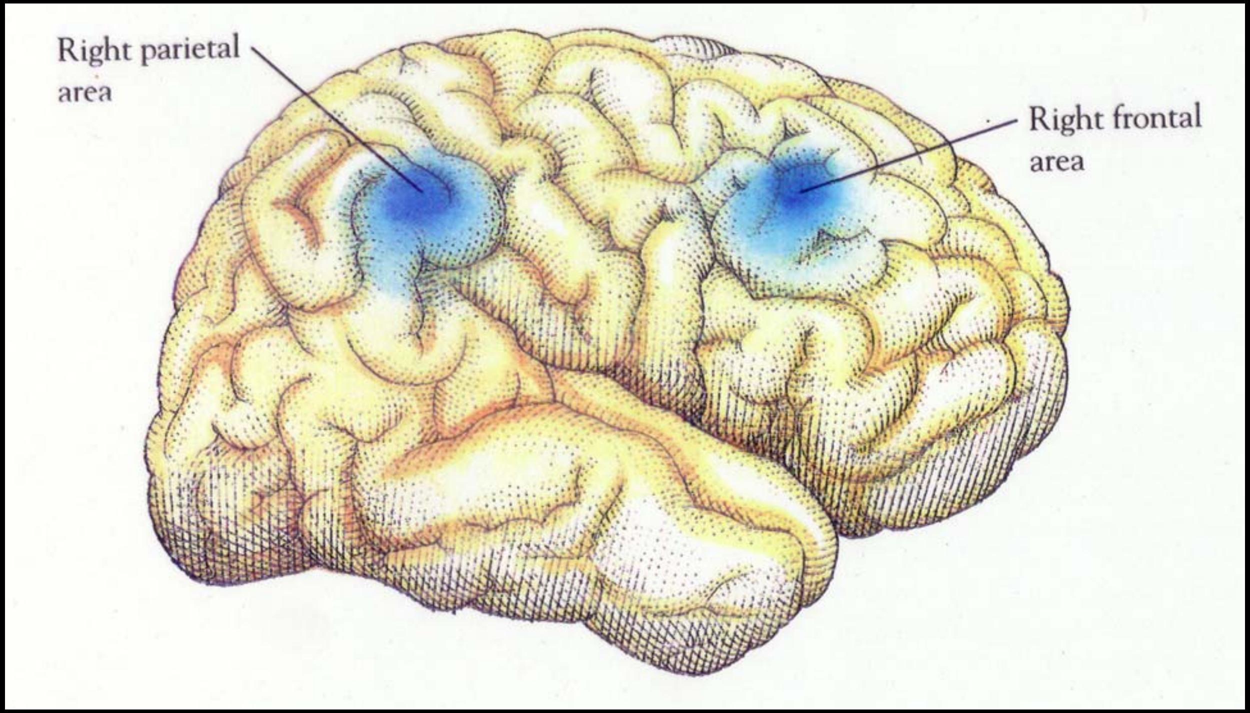
Selective Attention


Executive attention
Cingulate gyrus
Space
Working memory
Words
Visual orienting
Visual features


1. Posterior parietal lobe: DISENGAGE
2. Superior colliculus: MOVE
3. Pulvinar: ENHANCE


Right parietal area
Right frontal area

Hemispheric Specialization

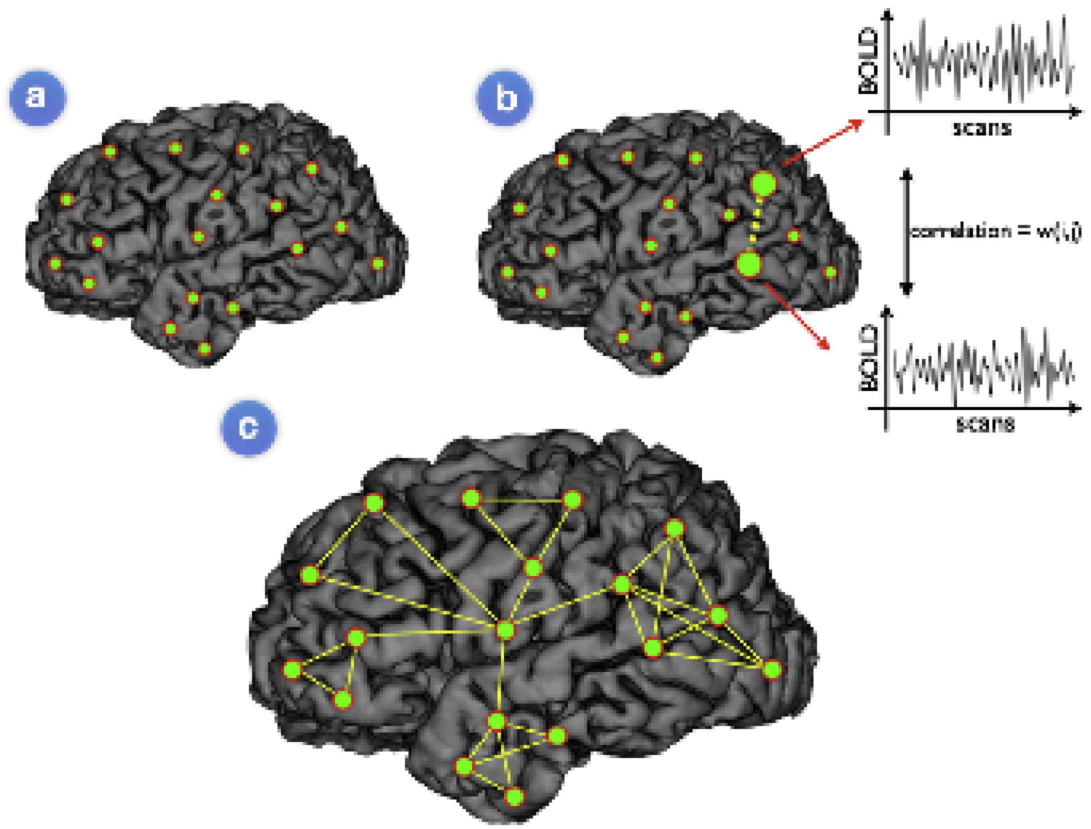


Figure 3 Modeling the functional brain network. The functional connected brain network can be represented as a graph, consisting of nodes, and edges (or connections) between regions that are functionally linked. First, the collection of nodes is defined. These can be brain regions, defined by a preselected template of brain regions, for example the Brodmann Areas (*panel a*). Second, the existence of functional connections between the nodes in the network needs to be defined, indicating the level of interaction between the nodes of the network. Within resting-state fMRI studies, the level of co-activation between brain regions is used as a measure of connectivity, defined by the level of correlation between the resting-state fMRI time-series. Within a graph approach, the level of functional connectivity between each possible pair of nodes in the network is computed (i.e. between all possible regions or voxel pairs), resulting in a connectivity matrix (*panel b*). Finally, the existence of a connection between two points can be defined as whether their level of functional connectivity exceeds a certain predefined threshold. This results in modeling the brain as a functional network with connections between regions that are functionally linked (*panel c*).

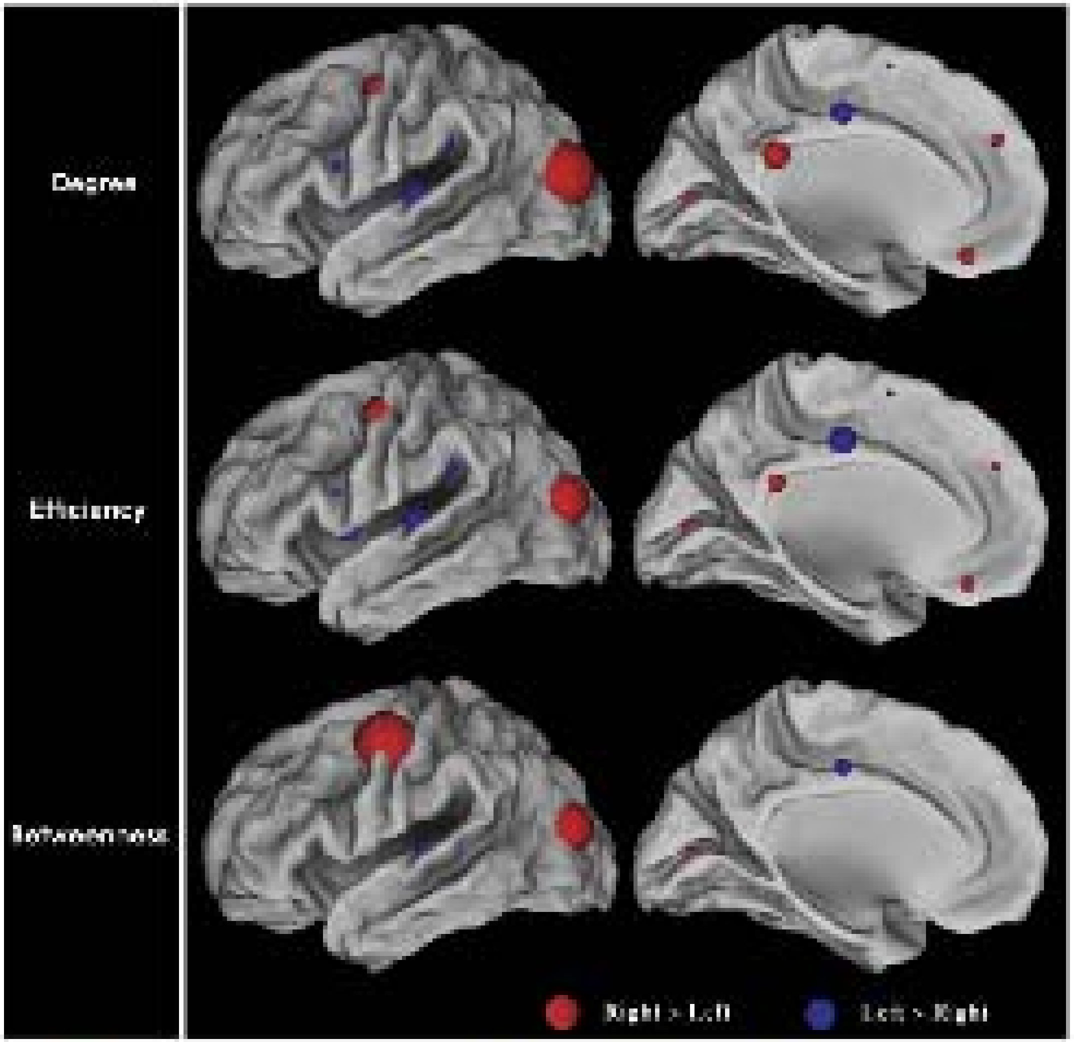
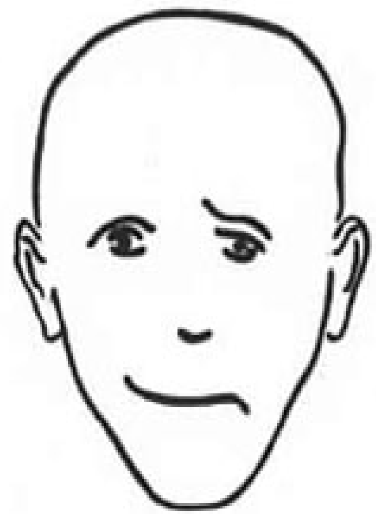


Fig. 5. Regions exhibited significant hemisphere-related differences in the regional nodal parameters. The node sizes indicate the relative significance of hemisphere-related differences in the nodal degree, nodal efficiency and nodal betweenness centrality. The red color represents rightward asymmetries, and the blue color represents leftward asymmetries. The threshold was $P<0.05$ (Bonferroni corrected). Also see Table 5 for more details.



These faces are mirror images of each other. Stare at the nose of each. Which face is happier?

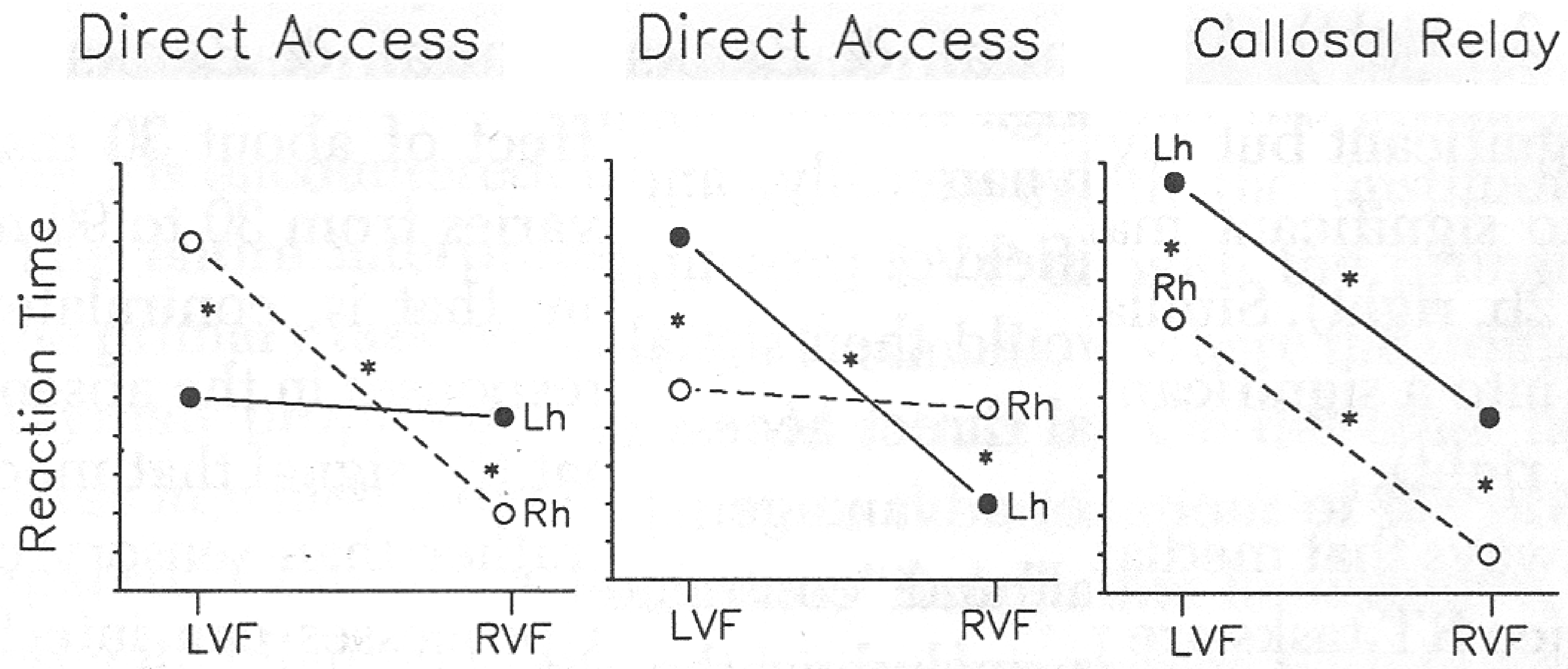
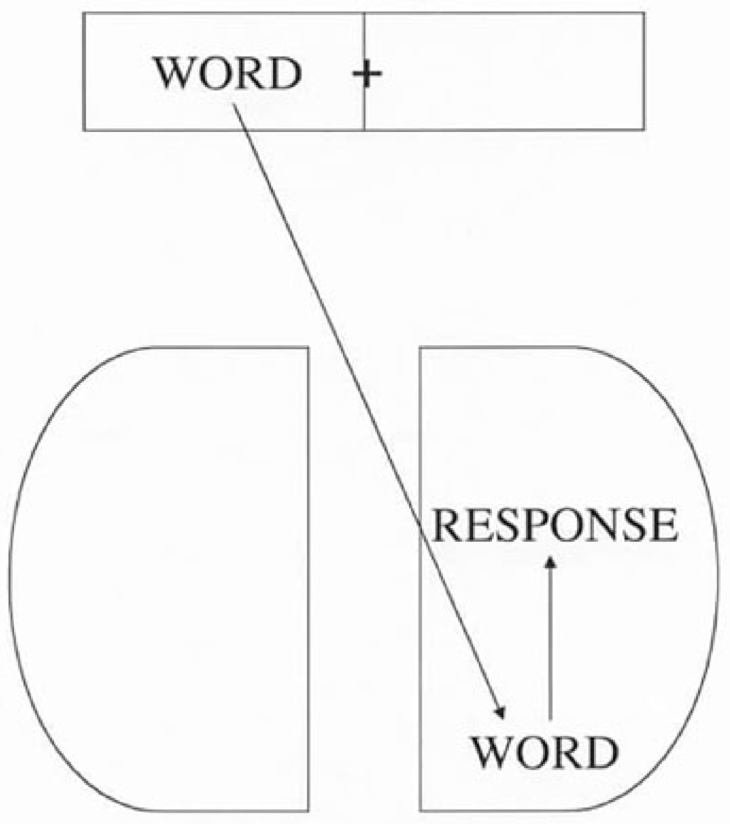
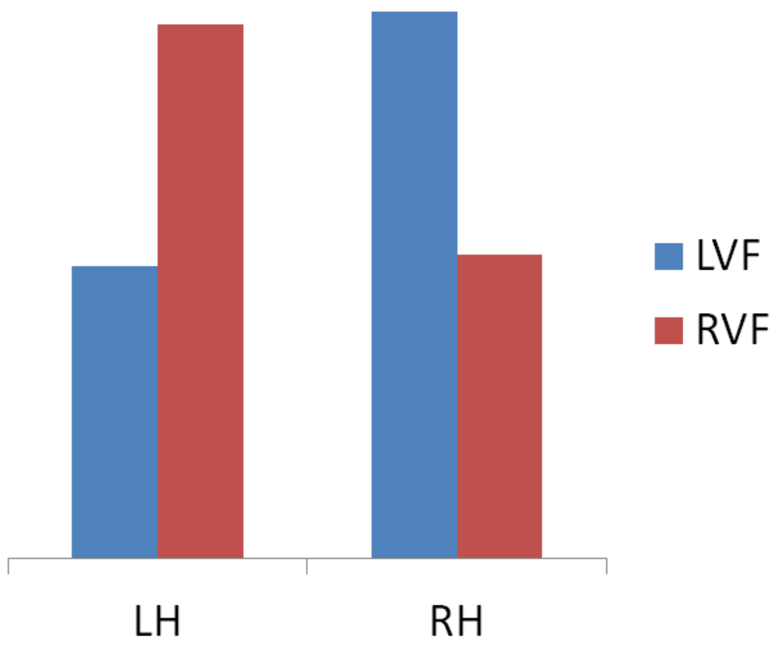


Figure 2. Patterns of possible interactions between visual hemifield of stimulus presentation and response hand in a lateralized tachistoscopic experiment. The figures on the left show h × VF plots; the figures on the right show plots of VF × condition. Condition has two levels: ipsilateral (RVF-Rh, LVF-Lh) and contralateral (RVF-Lh, LVF-Rh). (A) Callosal relay pattern reflecting exclusive specialization in the left hemisphere. (B) Direct-access pattern reflecting independent processing in each hemisphere. (C) Direct-access pattern with interference between central decision and response programming, reflecting hemispheric independence.

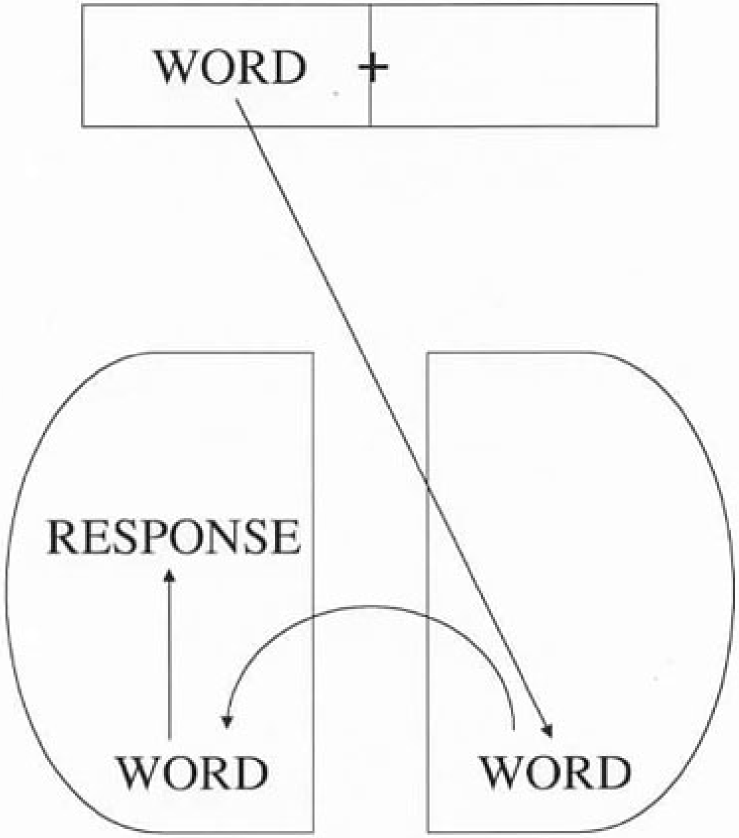
Patterns of Hemispheric Specialization: Direct Access



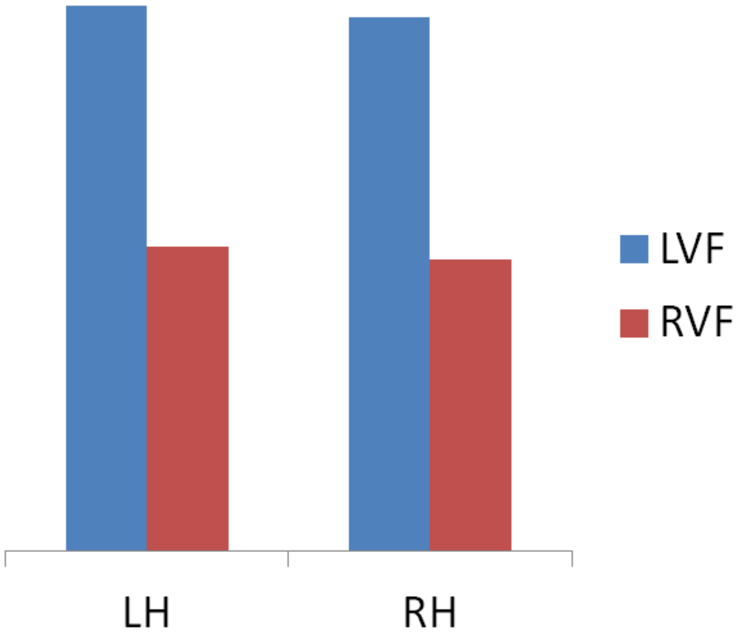
Direct Access



Patterns of Hemispheric Specialization: Callosal Relay



Callosal Relay



Hemispheric Attention

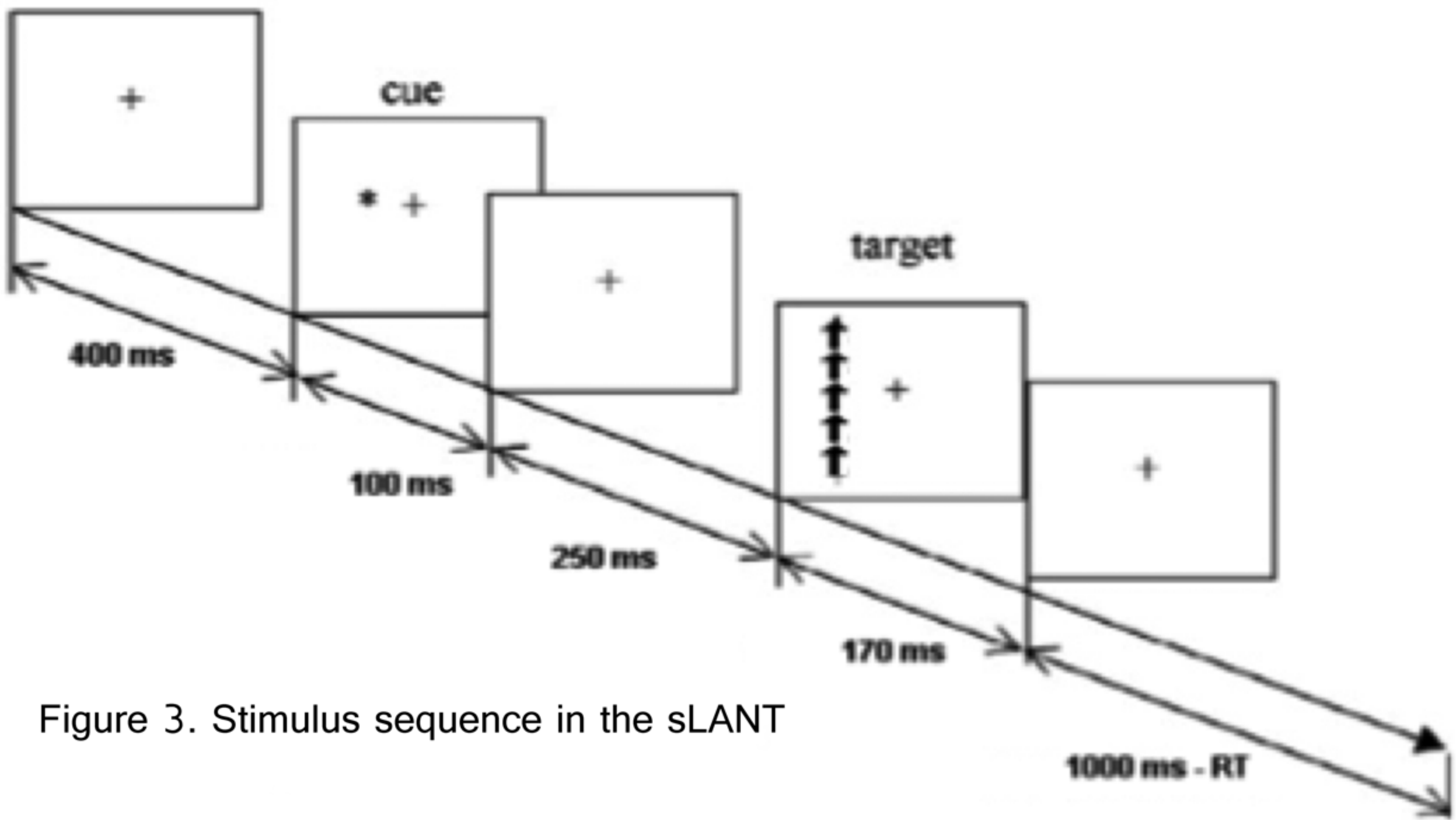


Figure 3. Stimulus sequence in the sLANT

Definitions:

1. Conflict:
   C = Targets with Congruent minus targets with Incongruent flankers

1. Orienting Benefit:
   OB = Targets with Valid minus targets with Central cue

1. Orienting cost:
   OC = Targets with Invalid minus targets with Central cue

4. Alerting:
   A = Targets with Double minus targets with No cue

- Bypassing evolution
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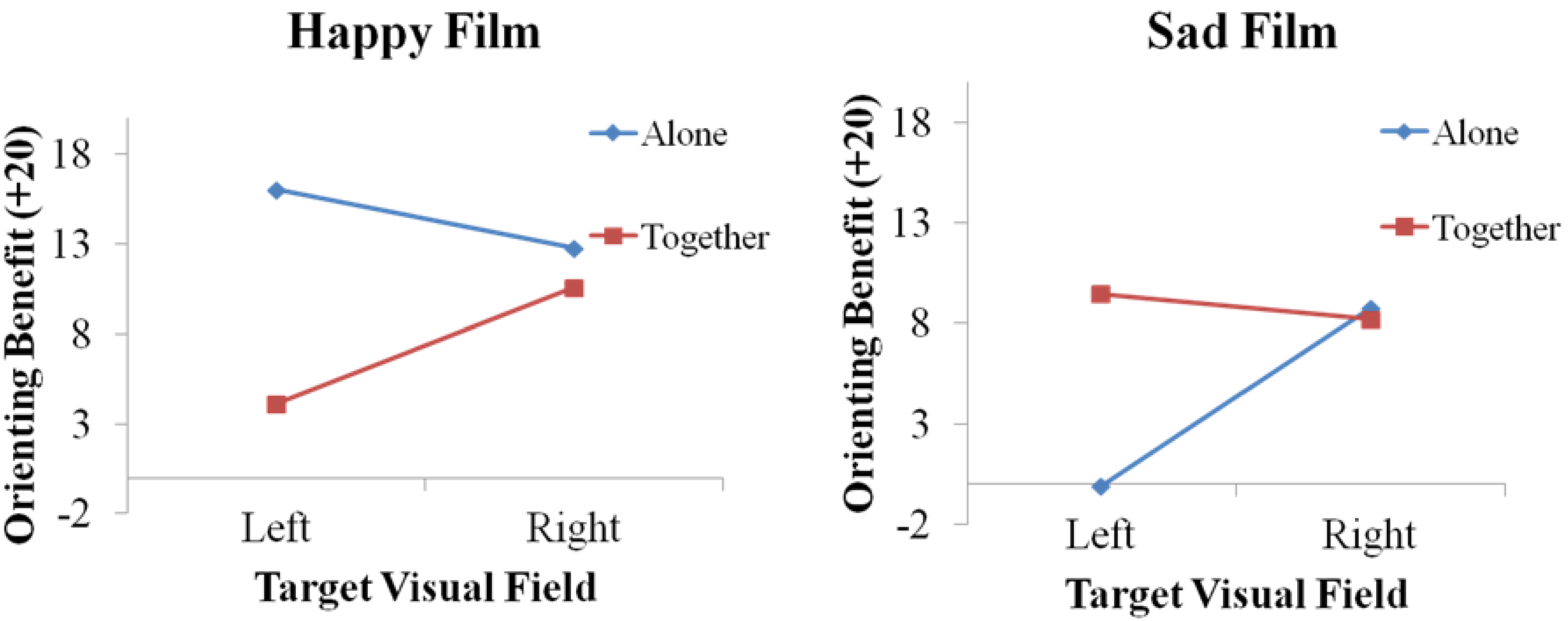
Fitting the task to the brain

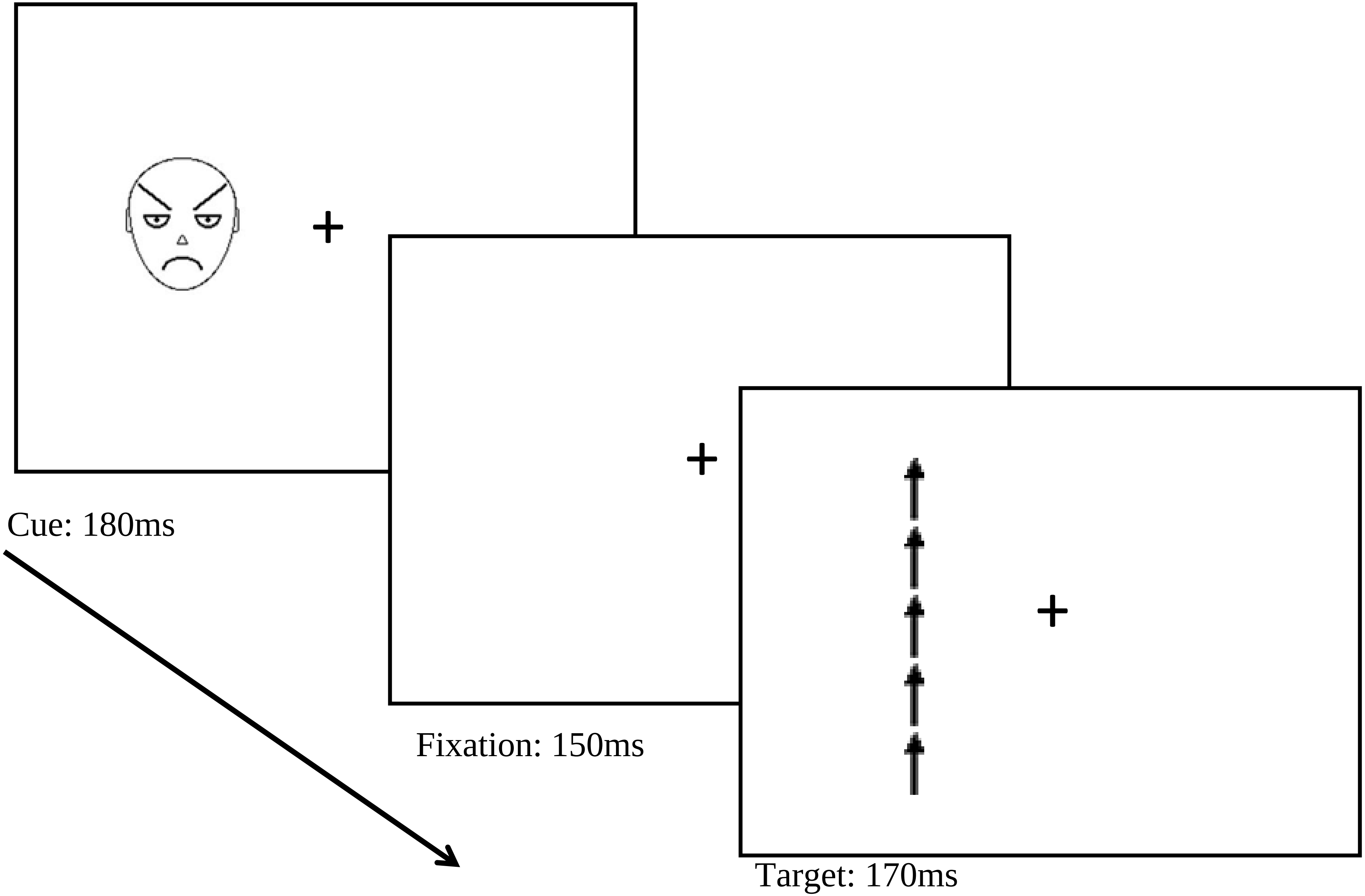
– Daily rhythms
– Fatigue
– Social Context

“The Brain in Film”   Psych 119G, Fall, 2010

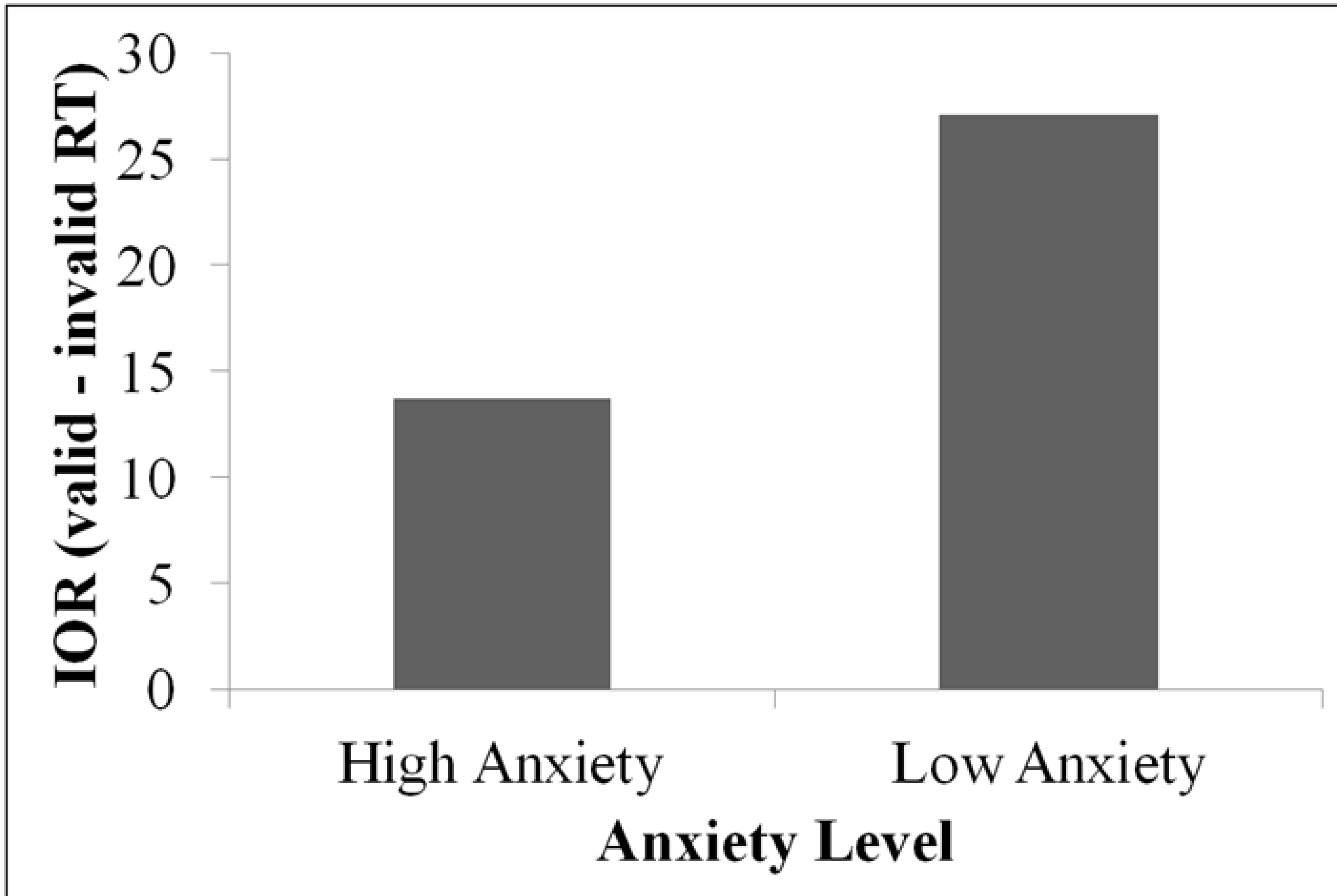
- Condition x Film x Target Visual Field



Experiment 3: Emotional LANT

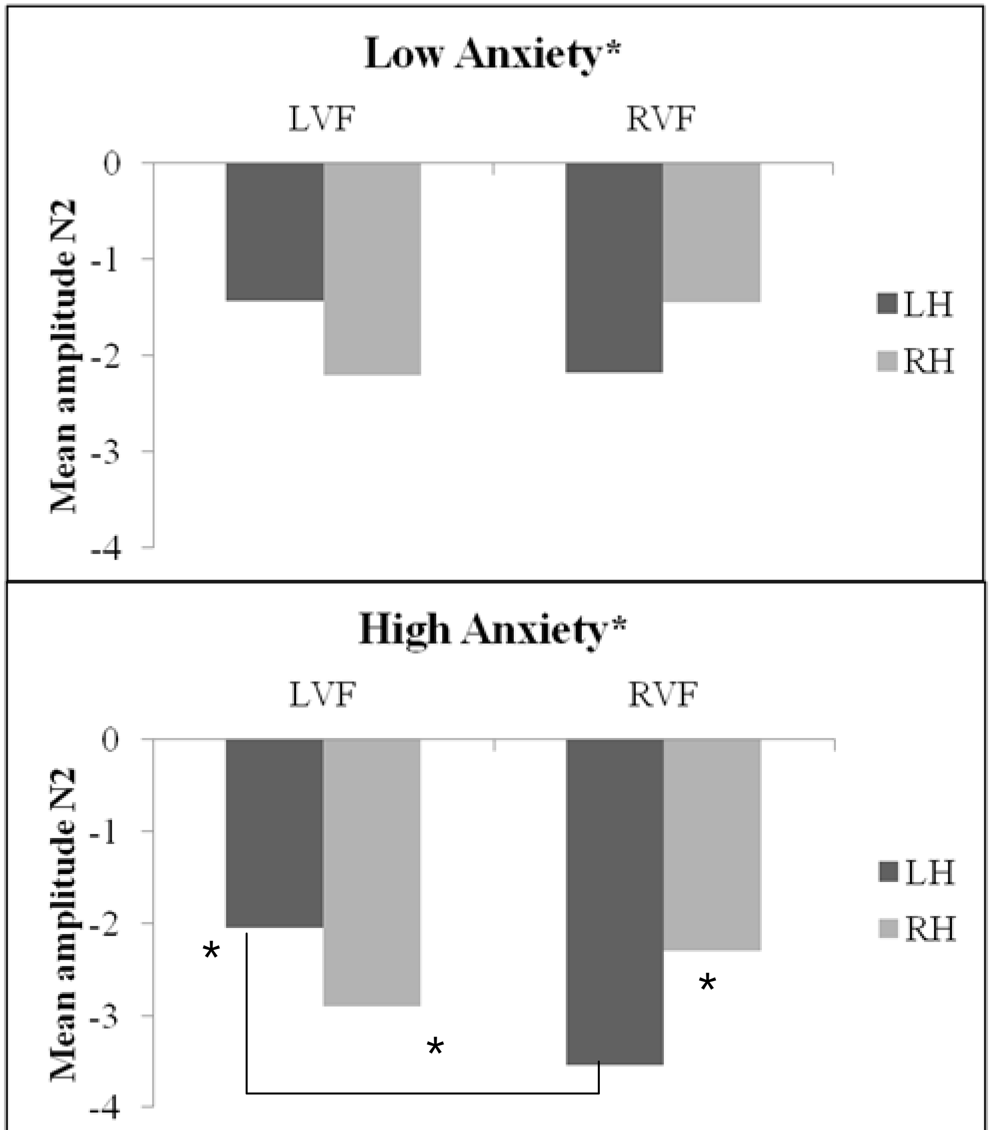


Main effect of Anxiety on IOR



STAI-TA score with IOR for RVF targets, r = -.476, p = .01

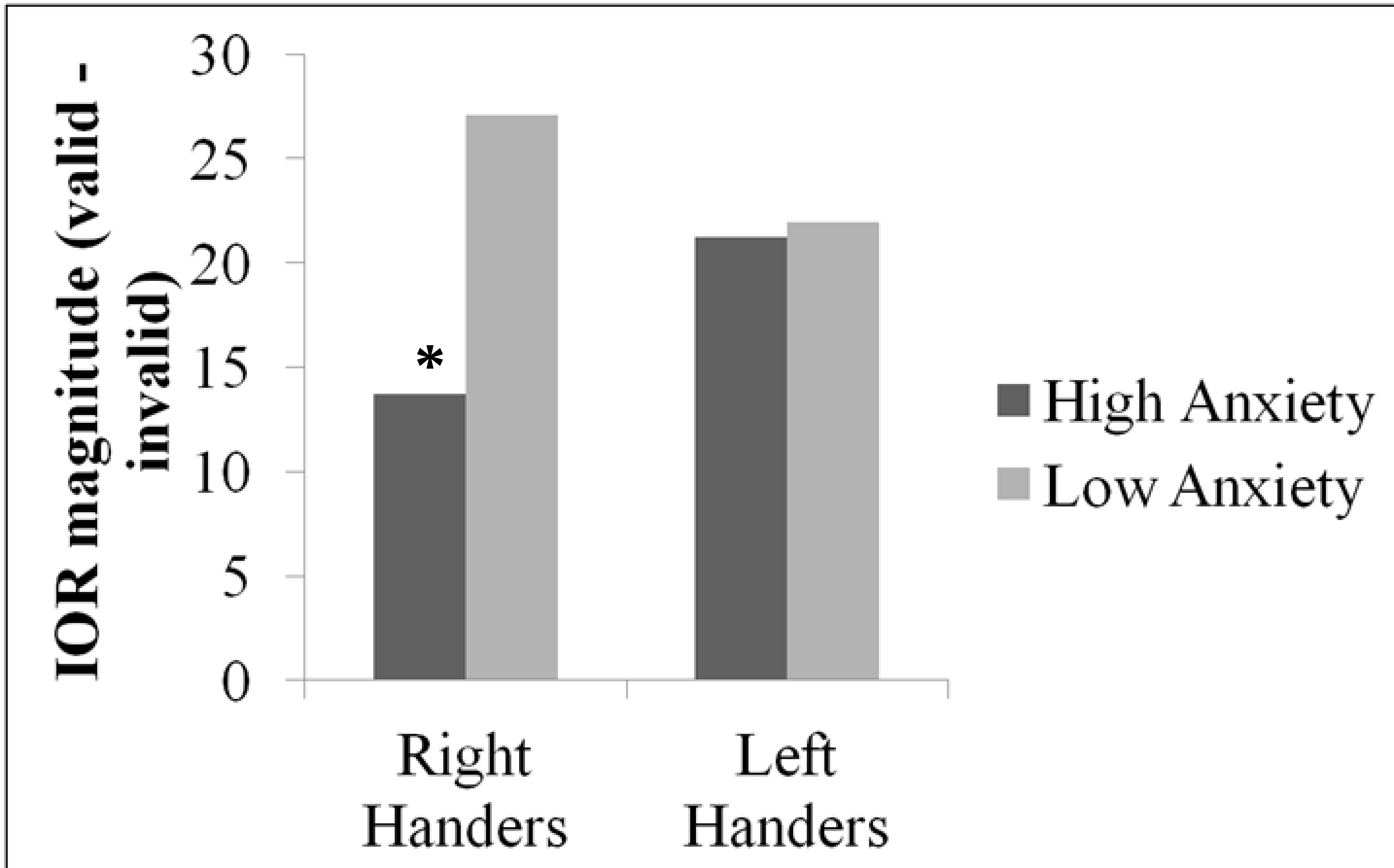
Interaction on mean amplitude N2: VF x Electrode x Anxiety



LH = P1 electrode
RH = P2 electrode

* Significant interaction $p < .05$

Interaction on IOR magnitude: Handedness x Anxiety, *p* = .08



- Right-Handers: STAI-TA and IOR RVF, $r = -.476$, $p = .01$
- Left-Handers: STAI-TA and IOR RVF, $r = -.04$, $p = .85$

Time Course of Events

Cue onset			**Target Onset**				**Target Onset (long delay)**		
	165 to 200ms	***200 to 270ms***	**Visual Probe**	***100 to 175ms***	***175 to 300ms***	***300 to 400ms***	**Covert Orienting, Long SOA**	***0 to 150ms***	***150 to 300ms***
	Valence x Anxiety x VF	Valence x Anxiety		Valence x Anxiety	VF x Congruity x Anxiety	Valence x Congruity x VF		Valence x Validity x Anxiety	VF x Anxiety
					VF x Anxiety			Anxiety	Valence x Anxiety
			Covert Orienting, Short SOA	***0 to 150ms***	***150 to 300ms***	***300 to 600ms***			
					Validity x Anxiety	Valence x Anxiety			

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EEG-Biofeedback

- Does it work?
  - Changing hemispheric specialization in children
  - Changing attention in ADHD
- How does it work?
  - The behavioral change
  - The physiological change
  - The feedback monitor

- Adapting the problem to the brain
  - Changing hemispheric specialization
  - Changing hemispheric attention
  - Recovering from brain damage

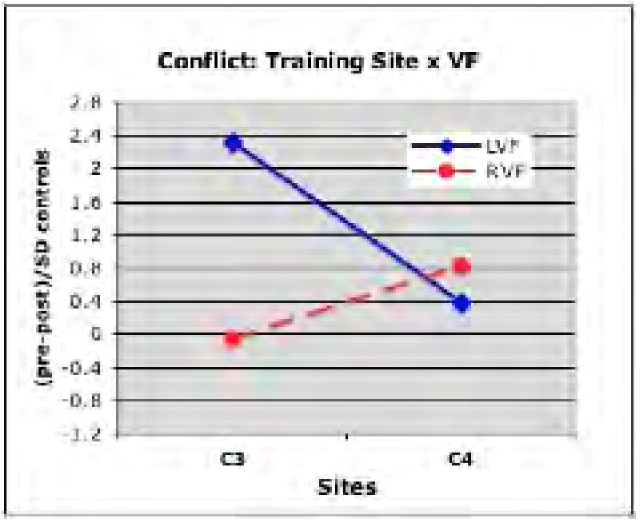


Figure 9. The effect of EEG biofeedback on the attention networks as a function of the training electrode.

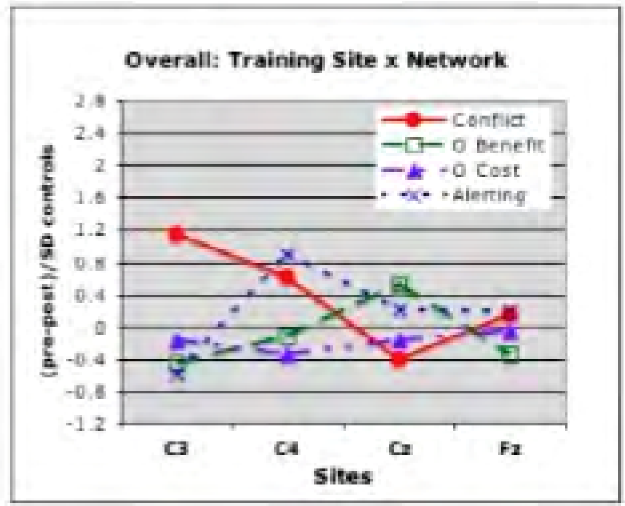


Figure 10. The effects of C3 and C4 EEGBF training on Conflict in the LH and RH.

How does EEGBF work?

- Changes during feedback
  - Changes in the ERP of the reward signal
  - Changes in the EEG spectrum

- Changes after feedback
  - Changes in the ERP of the sLANT
  - Behavioral changes in the sLANT

- Default Network hypothesis
  - Disengage Network
  - Self Network

Experiment Measures Summarized

- Speeded Test of Lateralized Attention (***sLANT***)
  - Behavior: ***Accuracy, Reaction Time***
  - ERP (***N1, P2, P3***)
  - Scalp estimates of ERPs

- EEG Biofeedback (***Sham, C3Beta, C3SMR, C4SMR***)
  - ERP to Reward (***P50, N1, P2***)
  - ERSP of ERP at C3 and C4
  - Eyes Open / Eyes Closed EEG

Methods: Hardware & Software

- Groups assigned one of 4 biofeedback protocols:
  - C3-A1 SMR (8), C4-A2 SMR (8), C3-A1 Beta (8), Sham (16)
- Five training sessions, five days in a row.

Day 1	Day 2	Day 3	Day 4	Day 5
LANT & BFB	BFB Only	LANT & BFB	BFB Only	LANT & BFB

- Training parameters:
  - Unified reward stimuli (meeting all thresholds) was provided by a brief tone and simultaneous visual reward ("4-Mation" game).
  - Reward threshold set at 70% of amplitude, Theta inhibit at 20%, High Beta inhibit at 15%
  - Auto-thresholds every 30 seconds (after manual the first 30 seconds to begin rewards).
- Assessment and Testing on days 1,3,5:
  - Full head EEG recorded using a BioSemi 64-channel cap, plus bipolar ear channels.
  - LANT (Lateralized Attention Network Test), before the daily biofeedback session.
    - EEGer software events (beep/reward onset) and LANT event (cue/target codes) were embedded with the BioSemi 66 channel recording.
  - Eyes Open, Eyes Closed, pre/post data sets were also gathered at the beginning and end of days 1,3,5.
- Biofeedback only on days 2,4 (omitting full-head recording).
- Daily Surveys on Sleep, Mood, and Attention were administered.

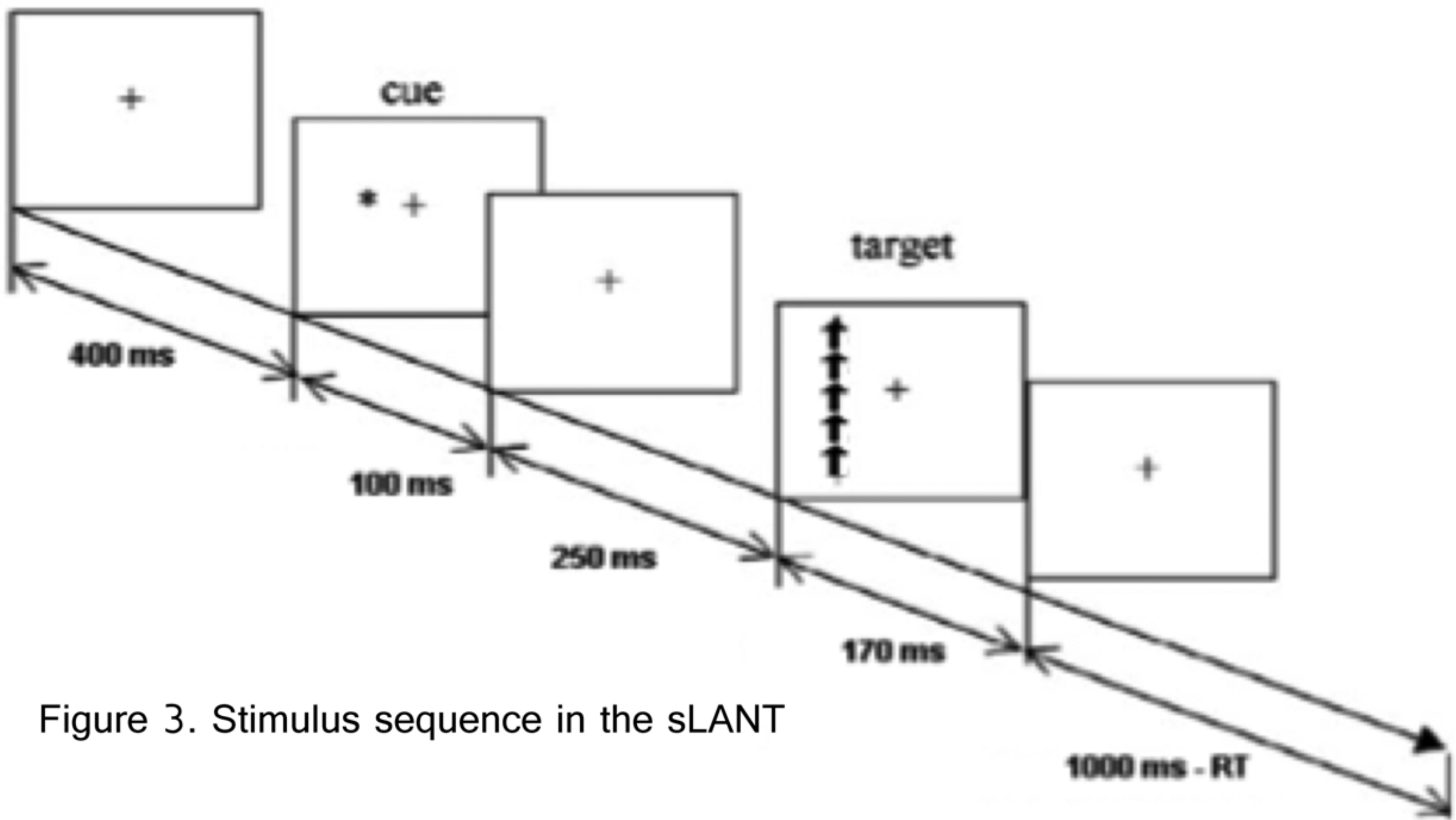


Figure 3. Stimulus sequence in the sLANT

sLANT

- Behavior
  - sLANT effects of Cue, Flanker, TVF similar to LANT
  - Main effects of Cue, Flanker, TVF on both RT and ACC
  - Conflict in RVF larger than LVF (RT)
- ERPs
  - N1,P2,(N2),P3
  - Lateralized Scalp ERP distribution
  - Conflict ERPs more anterior, Orienting ERPs more posterior
  - T-test visualization of Conflict & Orienting Cost
    - Conflict: posterior (bilateral) and right hemisphere
    - Orienting Cost: central & contralateral
- P3 Latency at C3, C4, correlated with behavior (RT & ACC)

Table 1: sLANT Performance: Reaction Time

sLANT 2x2x3 ANOVA (Reaction Time)

Variable	F	P
Flanker	79.89	0.001
Cue	18.14	0.001

All results significant at $p < 0.001$

- No RT effect of TVF
- Center Cues faster than Invalid Cues, slower than Center Cues
- Congruent Flankers faster than Incongruent

Table 2: sLANT Performance: Accuracy

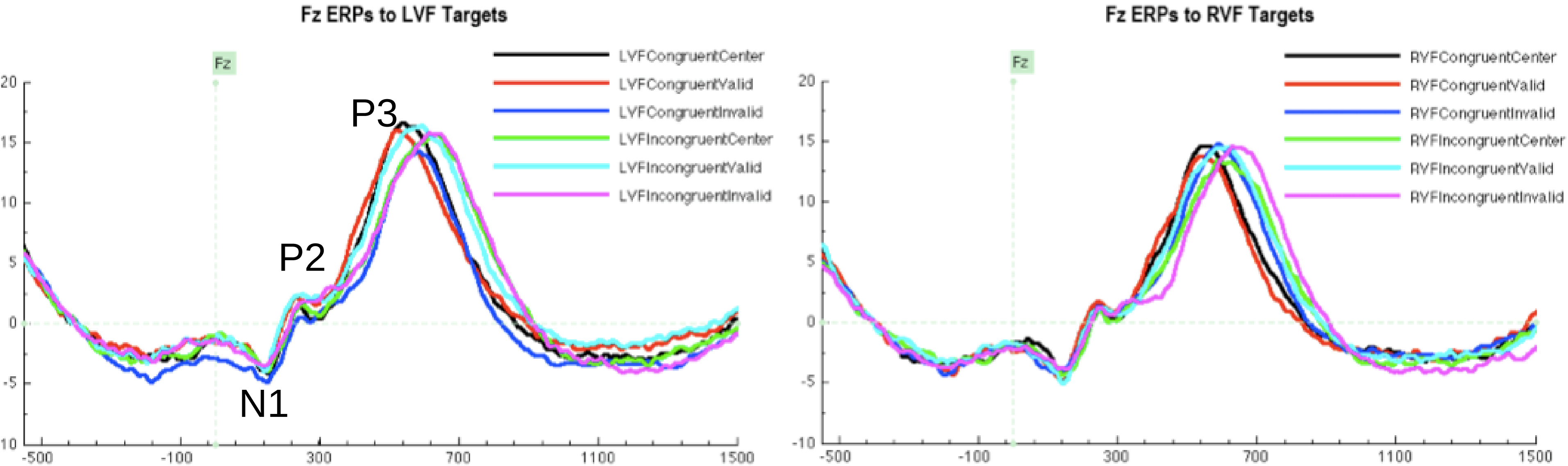
sLANT 2x2x3 ANOVA (Accuracy)

Variable	F	P
Target Visual Field	7.66	0.009
Flanker	97.03	0.001
Cue	18.90	0.001
TVF * Flanker	7.32	0.01
TVF * Cue	7.48	0.001

All results significant at $p < 0.01$

- LVF more Accurate
- Flanker effect (Conflict) larger in RVF
- Cue effect (Orienting) larger in LVF

Figure 2: sLANT ERPs that vary by Cue Validity & Flanker Congruity



Correlations between Behavior & ERP

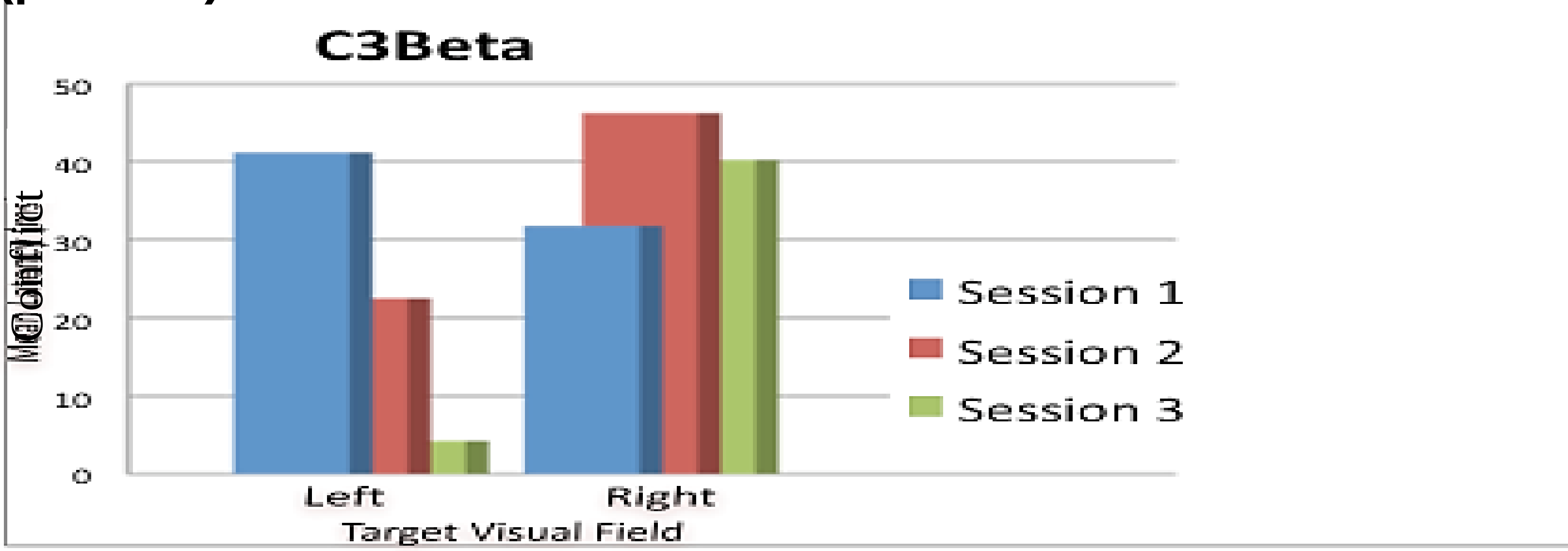
- C3
  - P3 Latency with sLANT RT ($r = .782$, $p = .002$)
  - P3 Latency with sLANT Accuracy ($r = -.872$, $p < .001$)
- C4
  - P3 Latency with sLANT RT ($r = .899$, $p < .001$)
  - P3 Latency with sLANT Accuracy ($r = -.903$, $p < .001$)

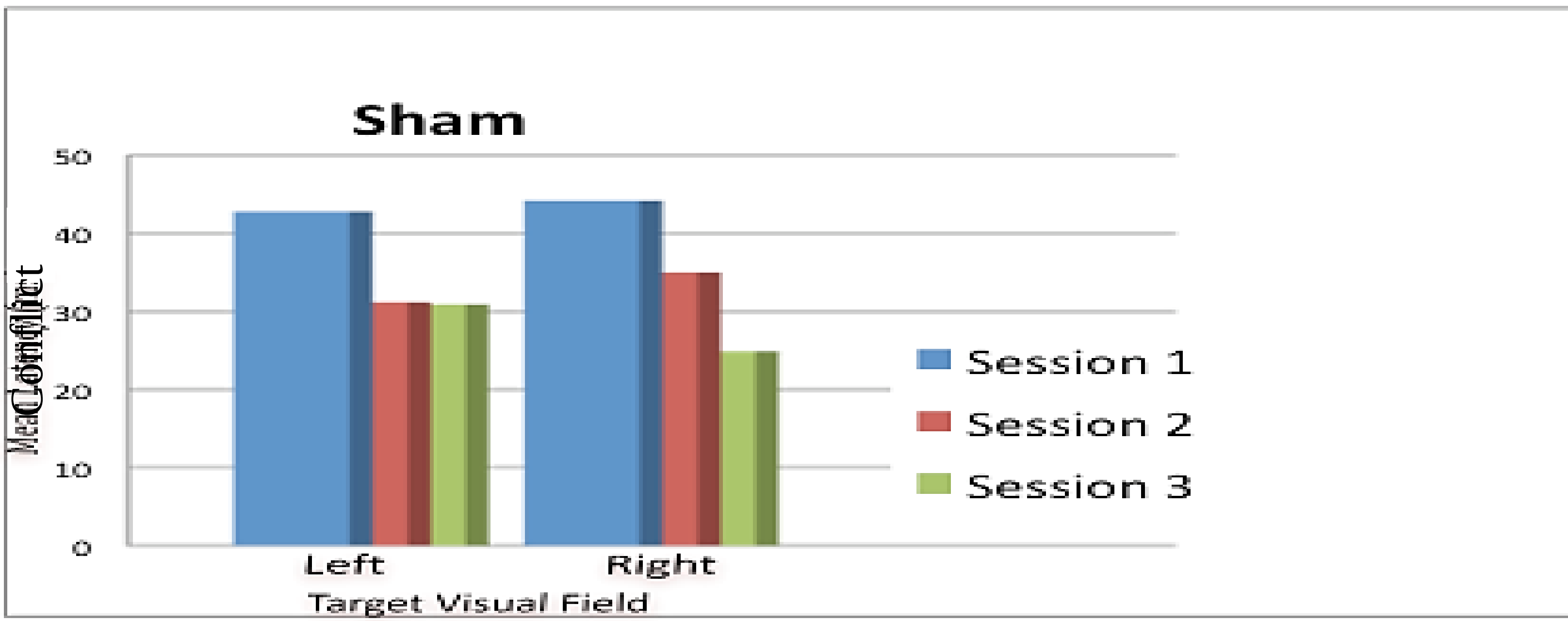
Effects of EEGBF on the sLANT

- Behavior
  - RT: Flanker * Session
  - ACC: Flanker * TVF thoughout
  - RT: ***TVF * Flanker * Session * Group***

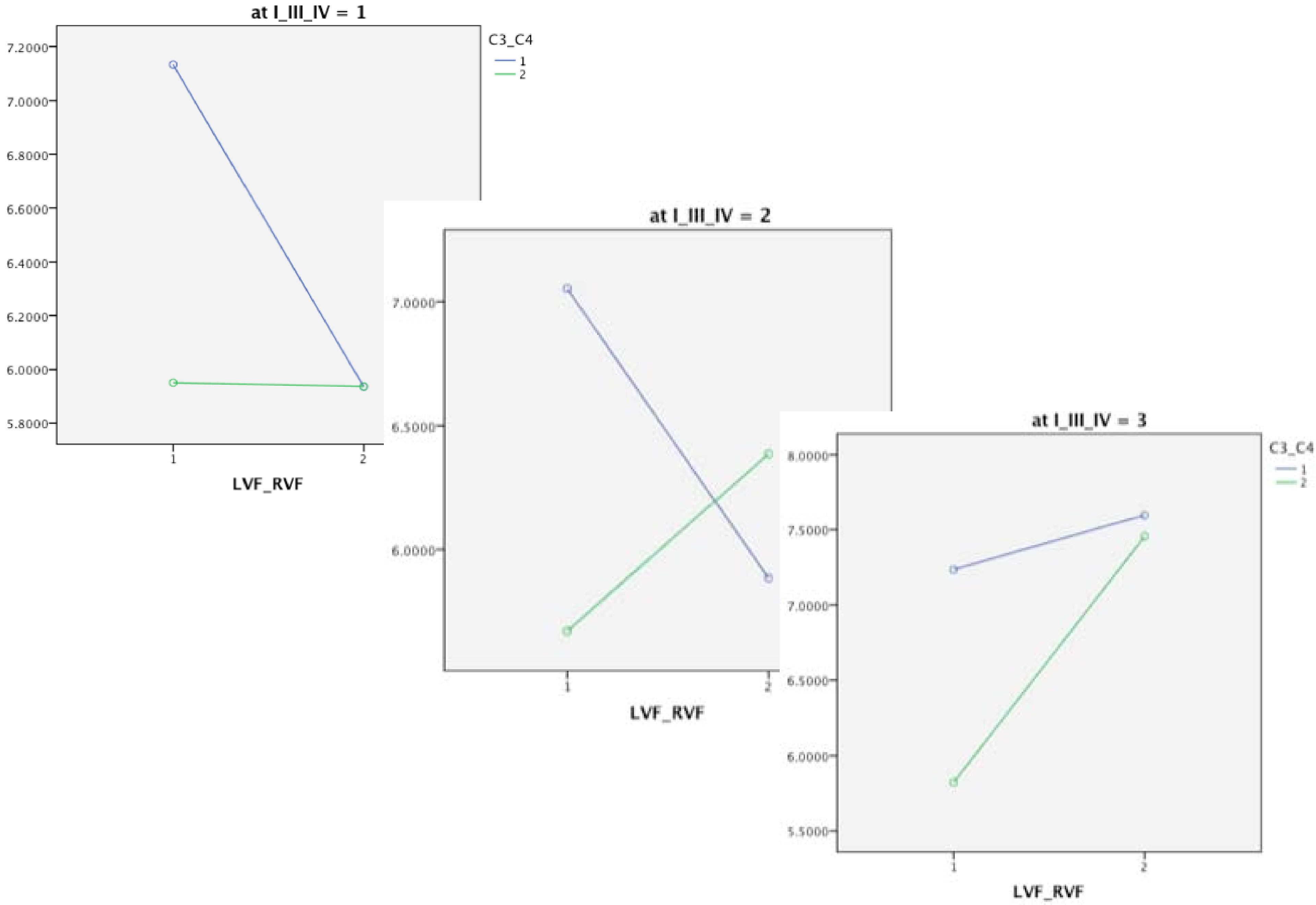
- ERP
  - Lateralized Scalp distribution
  - Group X Session effects
    - N1 Latency: ***C3 SMR v. Sham***
    - P3 Latency
    - P3 Mean Amplitude

C3Beta training selectively reduced Conflict in the right hemisphere (p = .053)

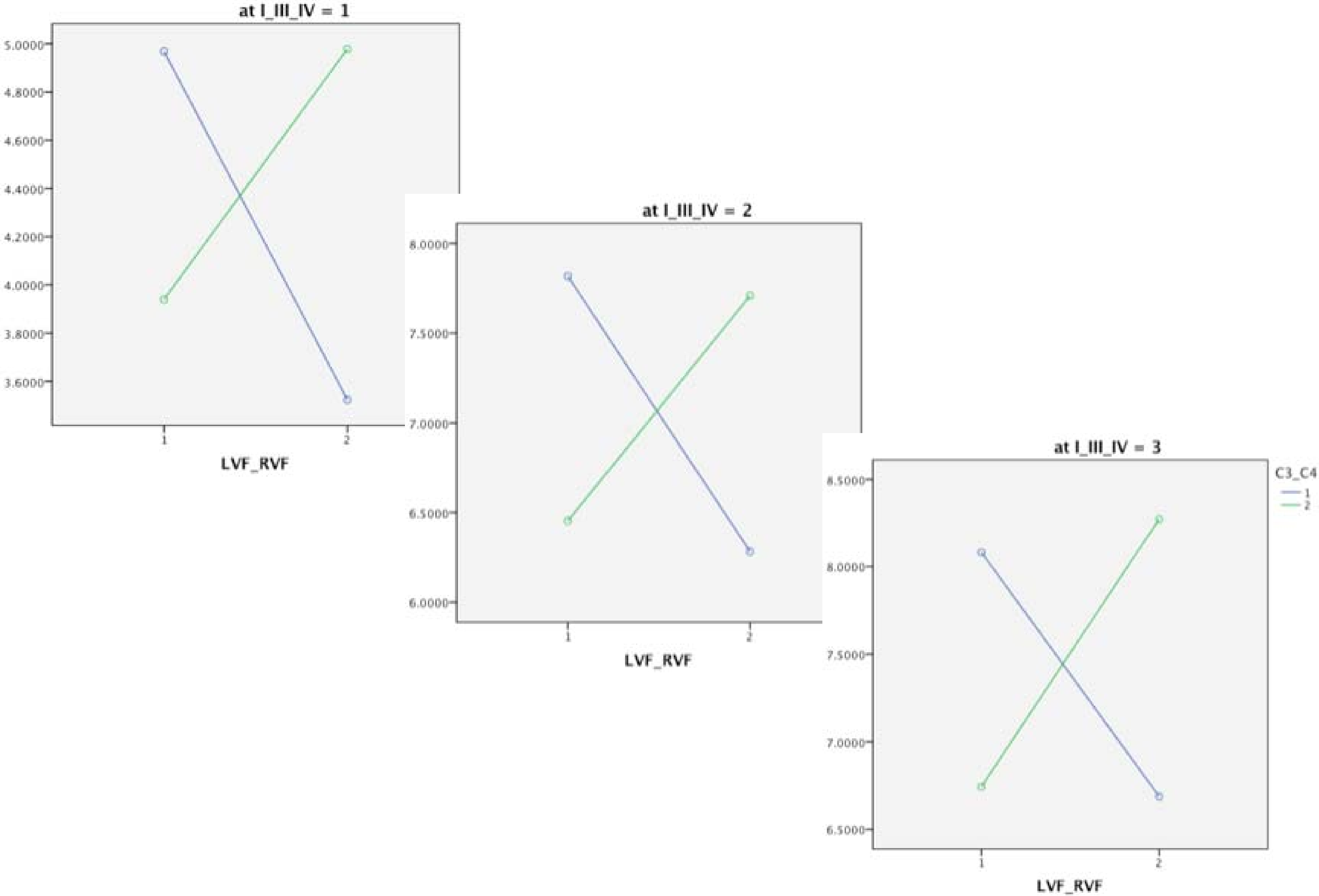




Ch2 Findings: TVF * Electrode (C3, C4) * Session: P3 Amplitude: SHAM



Ch2 Findings: TVF * Electrode (C3, C4) * Session: P3 Amplitude: C3 Beta



- Change in EC/EO EEG from each session, by group
  - EO change in Theta and Alpha for Sham; sig in SMR and Beta for Active
  - EC changes in Theta, Alpha, SMR, Beta for Active; not for Sham

Conclusions

- "Group * Session" interactions demonstrate that ***EEG Biofeedback acts in a protocol-specific way on***:
  - Behavior
  - ERP of behavior
  - ERP of Biofeedback reward
  - Resting EEG (eyes open / eyes closed)

Thus,

- ***Hemisphere of training*** electrode ***matters***.
- ***Reward frequency matters***.
- Blinded Sham/***Placebo EEG BFB training is possible***
- ***Reward frequency can be seen in ERSP***
  - ERPS may be used to determine if training is occurring in real-time
- ***Contralateral training protocols***
  - SMR at C3-A1 vs C4-A2) have ***complementary effects*** on behavior and EEG in each hemispheres
- ***C3 Beta*** appears to ***increase laterality*** / decrease interhemispheric transfer

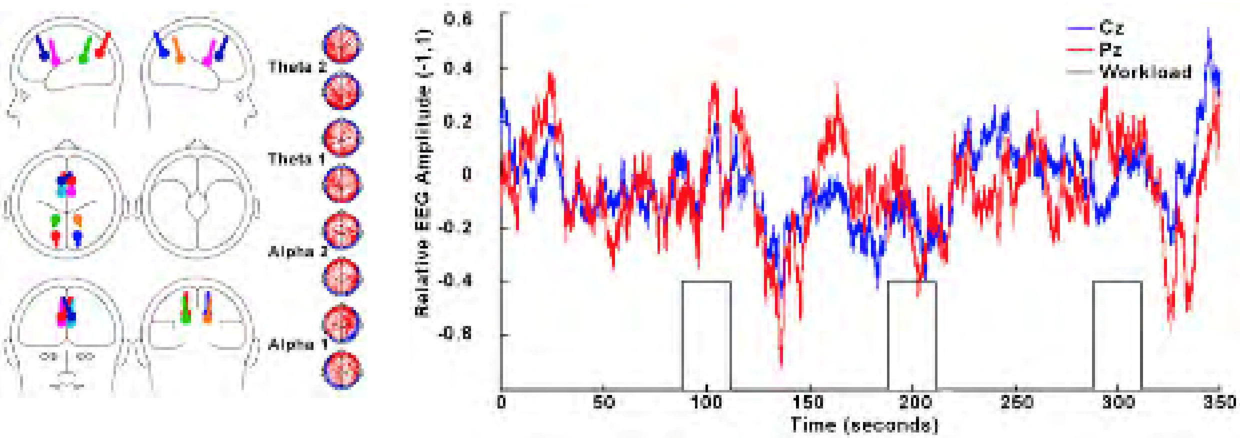


Figure 6. Left: CE2 BESA dipole simulator model including eight sources (LH, RH: alpha 1, alpha 2; LH, RH: theta 1, theta 2) showing views of equivalent dipole and corresponding reference-free EEG source-distributions. Right: EEG simulated with the CE2 8-source model including states of low and high workload. Electrodes Cz (blue) and Pz (red) are shown here. A total of 33 electrode recordings were simulated and processed using 3-D PARAFAC (parallel factor analysis), with dimensions of space (electrode), EEG power spectral density, and time (workload).

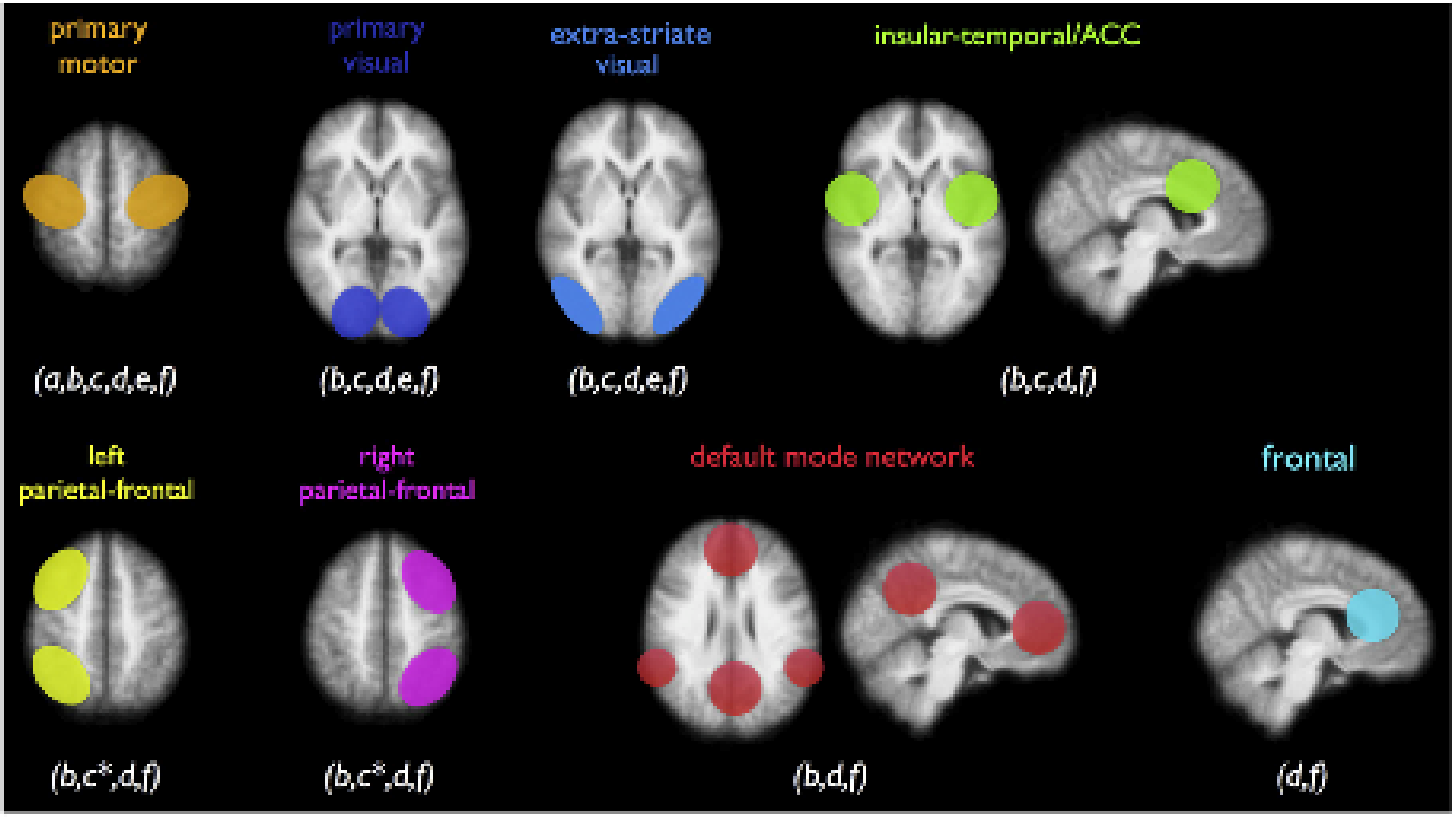


Figure 2 Resting-state networks. A number of group resting-state studies have consistently reported the formation of functionally linked resting-state networks during rest. These studies, although all using different groups of subjects, different methods (e.g. seed, ICA or clustering) (Beckmann et al., 2005; Biswal et al., 1995; Damoiseaux et al., 2006; De Luca et al., 2006; Salvador et al., 2005a; Van den Heuvel et al., 2008a) and different types of MR acquisition protocols, show large overlap between their results, indicating the robust formation of functionally linked resting-state networks in the brain during rest. This figure shows the most consistent reported resting-state networks across these studies, including the primary sensorimotor network, the primary visual and extra-striate visual network, a network consisting of bilateral temporal/insular and anterior cingulate cortex regions, left and right lateralized networks consisting of superior parietal and superior frontal regions (*reported as one single network) and the so-called *default mode network* consisting of precuneus, medial frontal, inferior parietal cortical regions and medial temporal lobe. The figure illustrates resting-state networks reported by the following studies: (a) Biswal et al. (1995), (b) Beckmann et al. (2005), (c) De Luca et al. (2006), (d) Damoiseaux et al. (2006), (e) Salvador et al. (2005a), and (f) Van den Heuvel et al. (2008a).

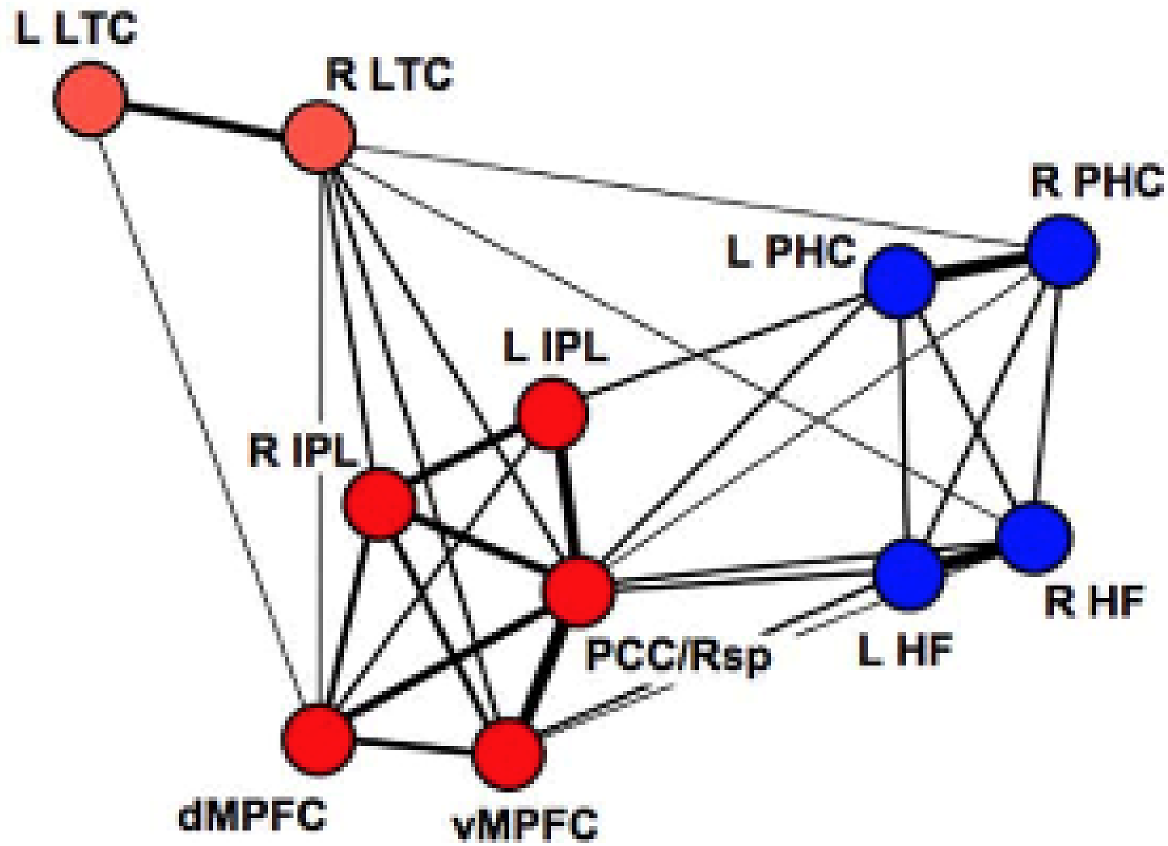


FIGURE 8. (top) Functional correlation strengths are listed for multiple regions within the default network. Each of the regions is displayed on top with the strengths of the region-to-region correlations indicated below (r-values were computed using procedures identical to Vincent et al. 2006). Regions are plotted on the averaged anatomy of the participant group (MNI/ICBM152 atlas with Z coordinates displayed). (bottom) The regions of the default network are graphically represented with lines depicting correlation strengths. The positioning of nodes is based on a spring-embedding algorithm that positions correlated nodes near each other. The structure of the default network has a core set of regions (red) that are all correlated with each other. LTC is distant because of its weaker correlation with the other structures. The medial temporal lobe subsystem (blue) includes both the hippocampal formation (HF) and parahippocampal cortex (PHC). This subsystem is correlated with key hubs of the default network including PCC/Rsp, vMPFC, and IPL. The dMPFC is negatively correlated with the medial temporal lobe subsystem suggesting functional dissociation. Graph analytic visualization provided by Alexander Cohen and Steven Petersen.

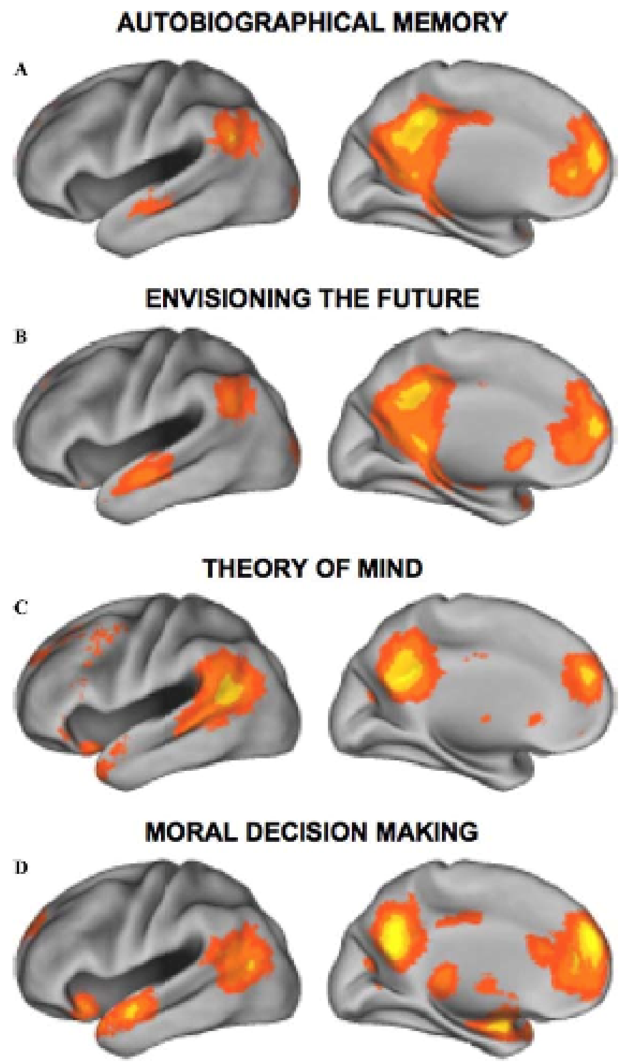


FIGURE 12. The default network is activated by diverse forms of tasks that require mental simulation of alternative perspectives or imagined scenes. Four such examples from the literature illustrate the generality. **(A)** Autobiographical memory: subjects recount a specific, past event from memory. **(B)** Envisioning the future: cued with an item (e.g., dress), subjects imagine a specific future event involving that item. **(C)** Theory of mind: subjects answer questions that require them to conceive of the perspective (belief) of another person. **(D)** Moral decision making: subjects decide upon a personal moral dilemma. Data come from prior studies and are here displayed using procedures similar to FIGURE 2. Data in A and B are from Addis et al. (2007). Data in C uses the paradigm of Saxe and Kanwisher (2003). Data in D is from Greene et al. (2001). Note that all the studies activate strongly PCC/Rsp and dMPFC. Active regions also include those close to IPL and LTC, although further research will be required to determine the exact degree of anatomic overlap. It seems likely that these maps represent multiple, interacting subsystems.

ANTICORRELATIONS

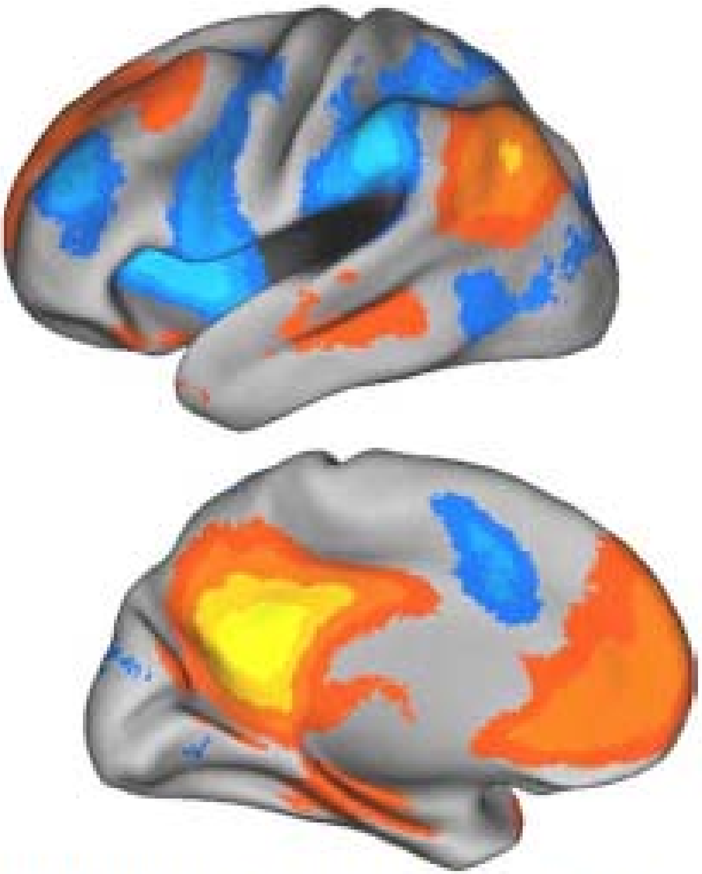


FIGURE 15. Intrinsic activity suggests that the default network is negatively correlated (anticorrelated) with brain systems that are used for focused external visual attention. Anticorrelated networks are displayed by plotting those regions that negatively correlate with the default network (shown in blue) in addition to those that positively correlate (shown in red). These two anticorrelated networks may participate in distinct functions that compete with one another for control of information processing within the brain. Data are the same as analyzed for FIGURE 7.

Next

- EEGBF and intra- / inter-hemispheric connectivity
- Real time automated EEG identification of task complexity and fatigue in each hemisphere
- Real time adjustment of hemispheric input/output resources using gaze contingent display
- Hemispheric EEGBF

- Bypassing evolution
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Some remaining issues

- The “neutral”
- Interhemisphericity vs. invalidity
- Are the attention networks a-modal?
- Orienting x Conflict
- “Mind states” (e.g., RT, Acc) vs. “brain states” (e.g., peak latency of ERP components)